



Armed Forces College of Medicine AFCM



Carbohydrates & protein digestion

Dr. Naglaa Fathy, MD

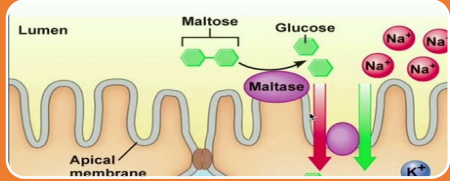
INTENDED LEARNING OBJECTIVES (ILO)



By the end of this lecture the student will be able to:

- 1- Outline phases of carbohydrate & protein digestion
2. Categorize different digestive enzyme needed for carbohydrate & protein digestion
3. Summarize absorption of amino acids
4. Correlate clinical disorders to enzyme deficiencies.

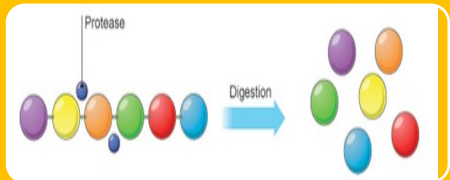
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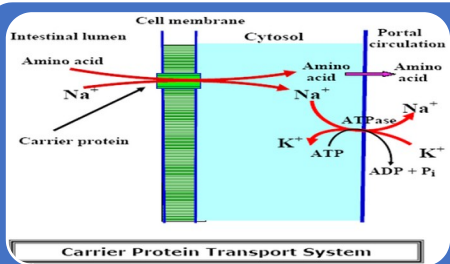
Carbohydrates digestion



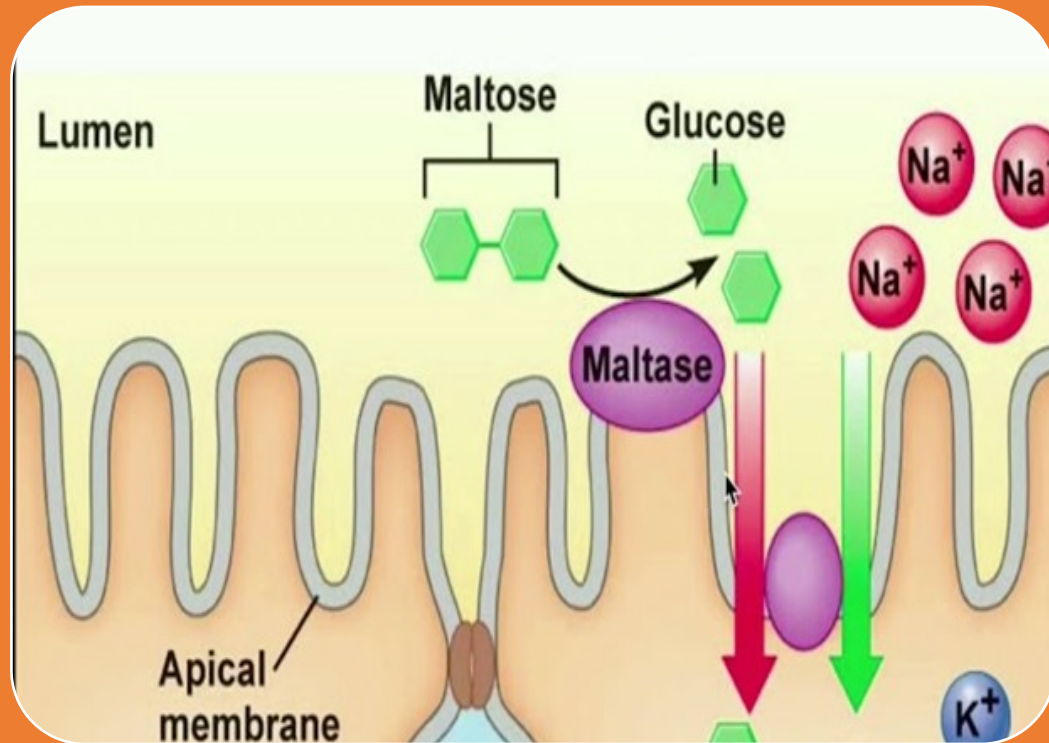
Lactose intolerance and sucrase-isomaltase deficiency



Protein digestion



Absorption of amino acids



Carbohydrates digestion

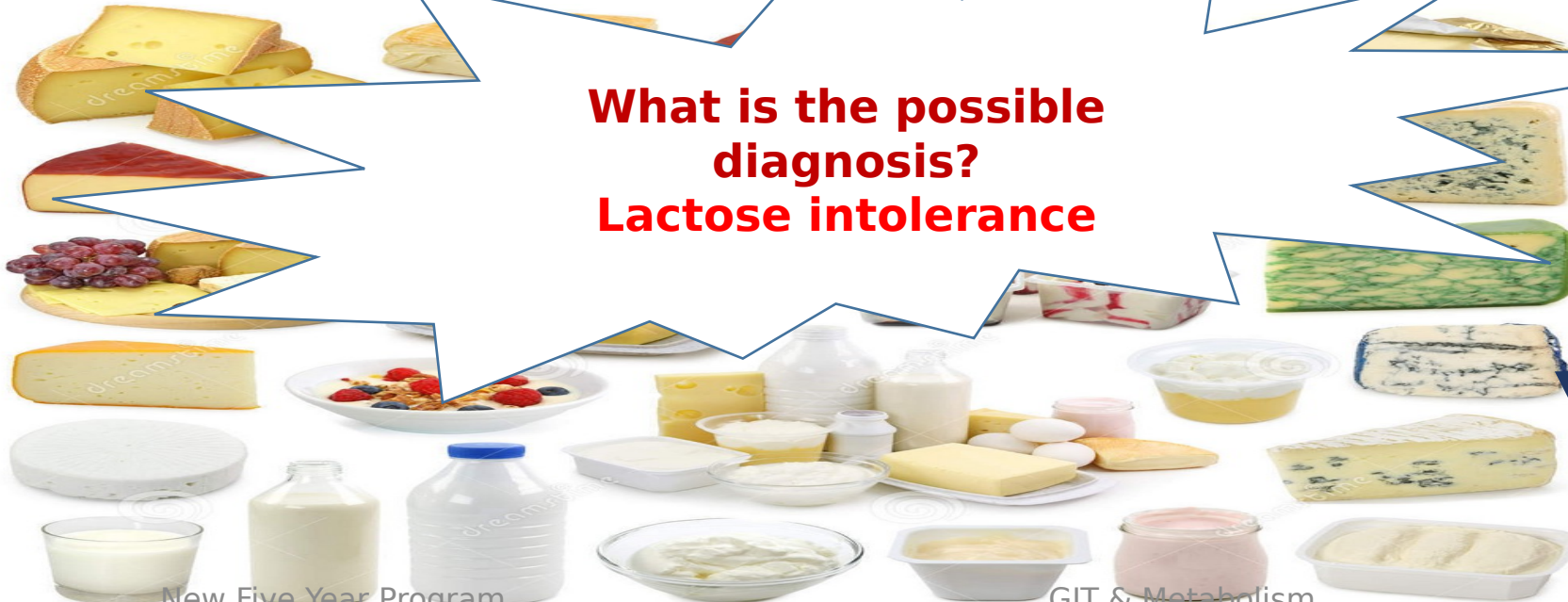
Clinical case scenario



A 6-year-old girl presents to her primary care physician with **abdominal pain, bloating, flatulence, and diarrhea** after **drinking milk**. She has a past history of similar symptoms after **eating any dairy product (including yoghurt and ice cream)**.



What is the possible diagnosis?
Lactose intolerance



Dairy products

Carbohydrates are classified according to products of hydrolysis into:



Carbohydrates

MONOSaccharides

1 sugar unit

Glucose, Fructose, Pentose



No need for digestion

Disaccharides

2 sugar units

Lactose, Maltose, Sucrose



Digestible

OLIGOSaccharides

(3-10) sugar units

POLYSaccharides

> 10 sugar units

GI &

Starch, Glycogen



Cellulose is Not Digestible

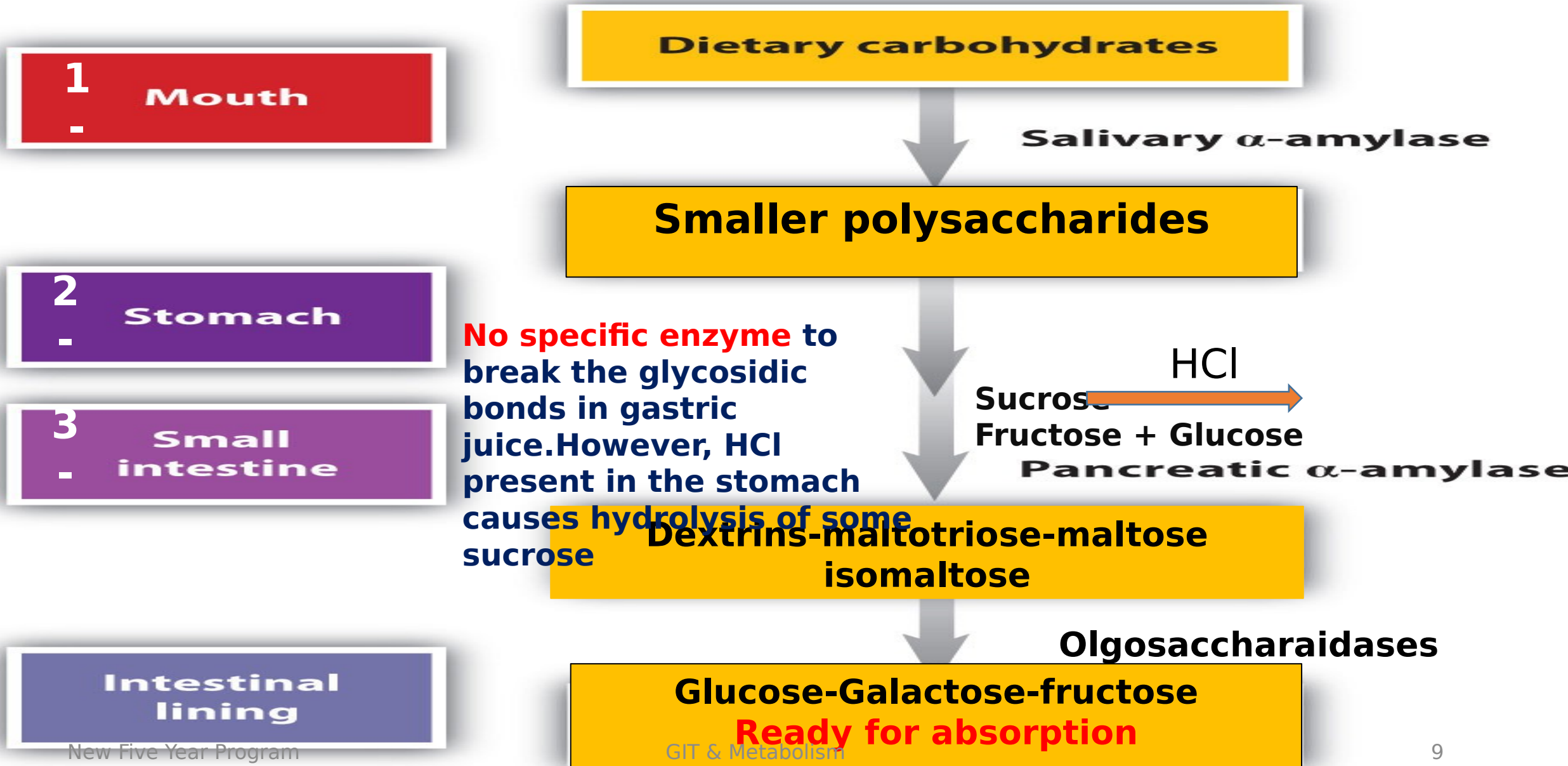
- **Cellulose**

- ***It is formed of glucose linked by β 1-4 glycosidic bonds. GIT enzymes don't act on β form of the bond .***
- ***It forms the bulk of stool & and prevent constipation***



<https://www.newfoodmagazine.com/article/26512/cellulose-food-environmentallyfriendly/>

Stages of carbohydrates digestion





Amylases

Salivary amylase (ptylin)

Starts **in the mouth** during mastication

It hydrolyses **α -1 \rightarrow 4 glycosidic** linkages of the polysaccharides (starch and glycogen).

It requires **Cl⁻** ion for activation

Optimum pH of **6.7**. its action stops in the stomach when the pH falls to 3

short duration of food in mouth

Pancreatic amylase (amylopsin)

Starts when Food bolus meets the pancreatic juice **in the duodenum**

Optimum pH=**7.1**

Longer time of food in the

Pancreatic amylase



It is an **endoglucosidase** = **can not give free glucose**)

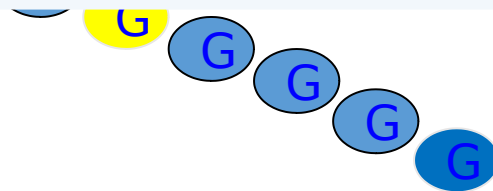
Starch/Glycogen

***Maltose/ Isomaltose/
Dextrins and
oligosaccharides***

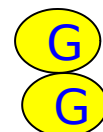
extrins

altotriose

α 1-4 link



maltose

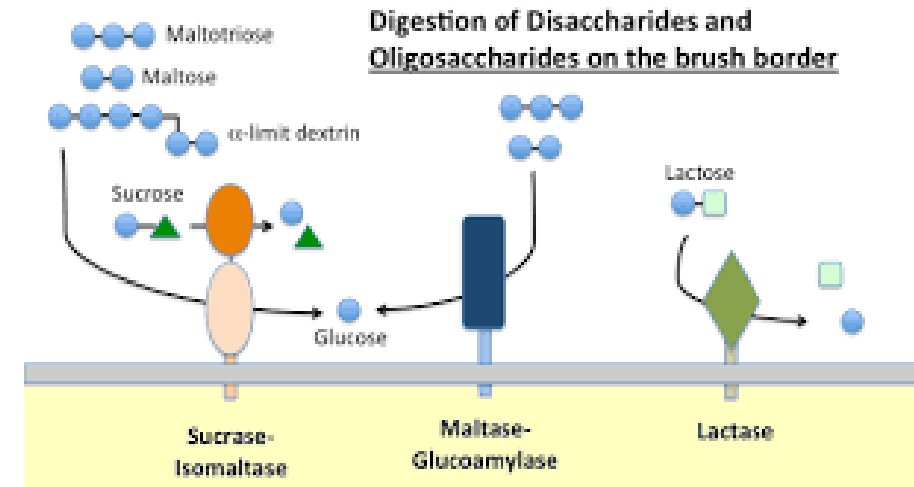


isomaltose

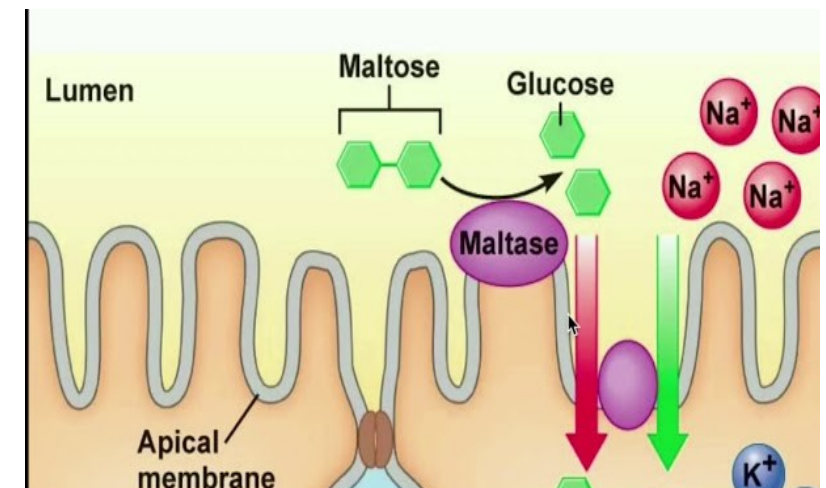
Oligosaccharidases



- They are synthesized by intestinal epithelial cells and present on the surface of brush border of these cells as integral membrane glycoproteins
- They act on the products of α amylase digestion of polysaccharides together with the ingested disaccharides
- They include: **Maltase, Isomaltase, Sucrase, Lactase.**



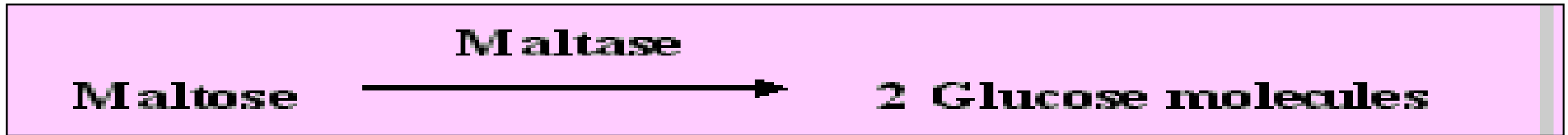
<http://www.vivo.colostate.edu/hbooks/pathphys/digestion/smallgut/benzymes.html>



<https://www.youtube.com/watch?v=dERCrrzNRL8>

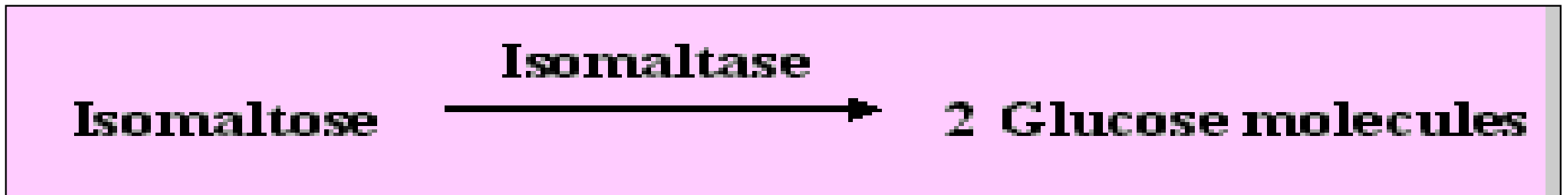
1. Exo α 1-4 glucosidase (maltase):

It can release the terminal glucose subunits linked in α 1-4 glycosidic linkages of dextrans or maltose.



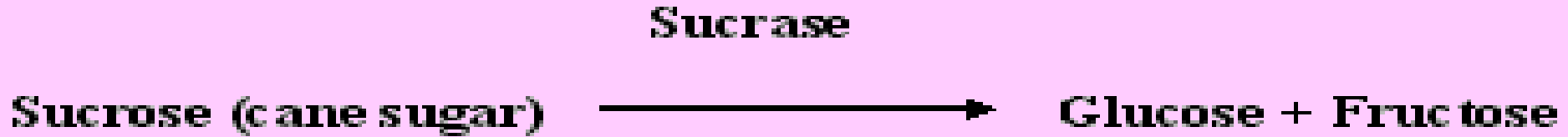
2. Isomaltase:

It can hydrolyze the α 1-6 glycosidic bond of isomaltose



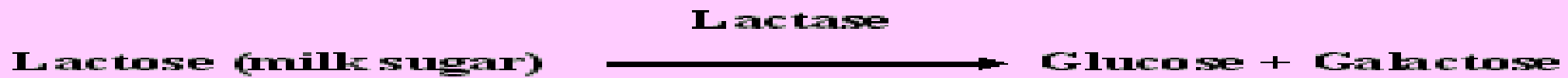
3. Sucrase:

It can hydrolyze the α 1-2 glycosidic bond of sucrose to release glucose and fructose.



4. Lactase:

It hydrolyses β -1,4-glycosidic linkage lactose to glucose and



So the end product of carbohydrate digestion

Glucose-Galactose-fructose
Ready for absorption

USMLE Quiz



A 50-year-old female presents with severe abdominal pain. Her serum amylase and lipase levels are abnormally elevated and she is diagnosed with pancreatitis. Which linkage between glucose residues is cleaved by amylase?

a) α -1,4

b) α -1,6

c) β -1,4

d) α 1,2

e) β -1,6





Lactose intolerance and sucrase-isomaltase deficiency

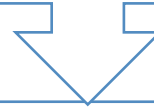
Lactose intolerance

- It is a condition resulting from Lactase deficiency.
- Lactase is responsible for breaking down lactose into glucose and galactose, which are absorbed.
- The clinical symptoms of lactose intolerance follow **dairy product** (milk, yoghurt, ice creme) intake.

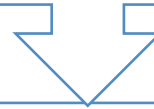


Biochemical basis of Lactose intolerance

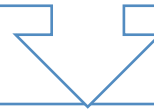
Absence of lactase in the brush border of the small intestine.



The osmotic effect of the undigested and unabsorbed lactose leads to an influx of fluid in the lumen of the small intestine



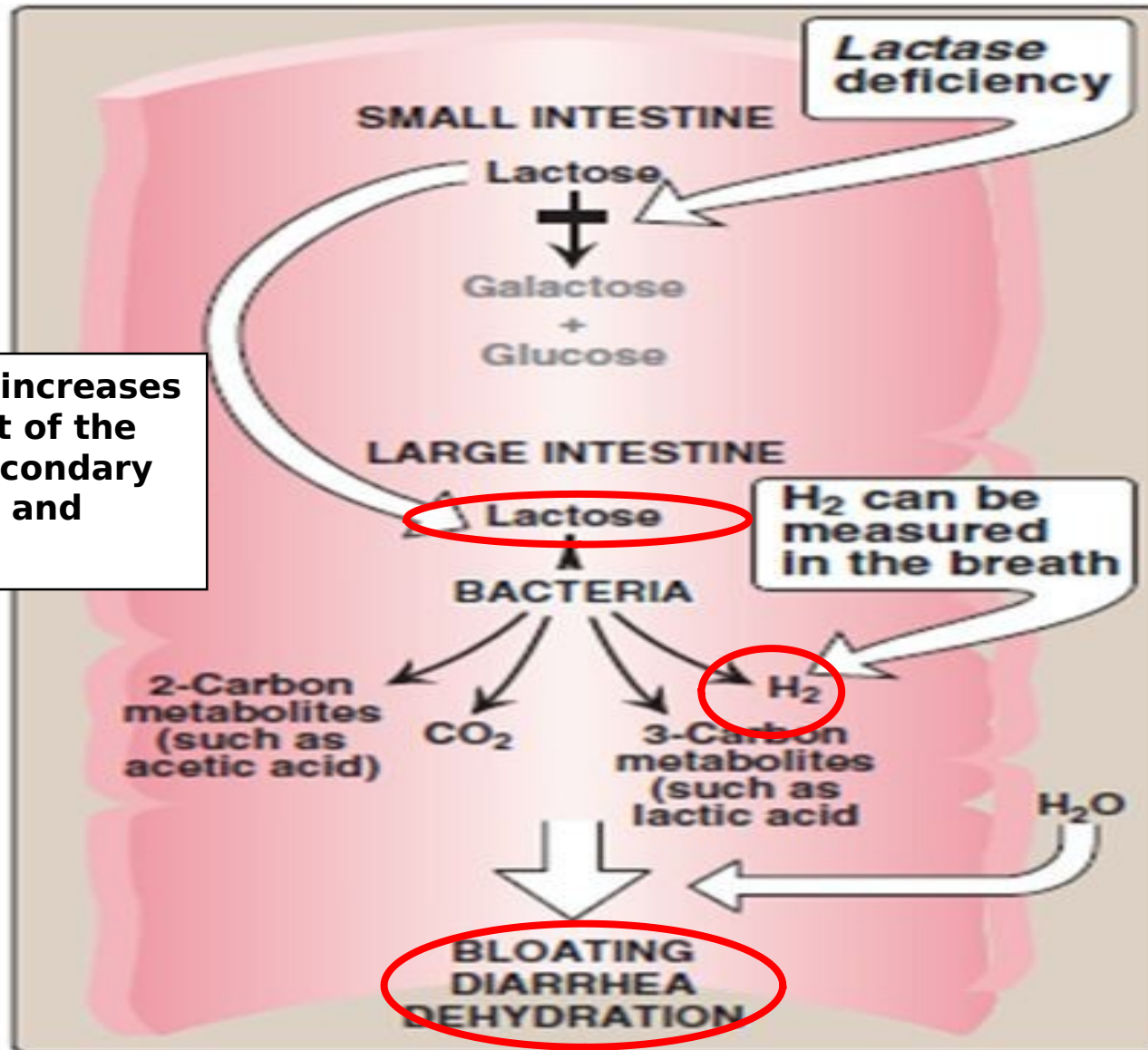
The increased retention of fluid results in the symptoms of diarrhea with its abdominal distention and cramping.



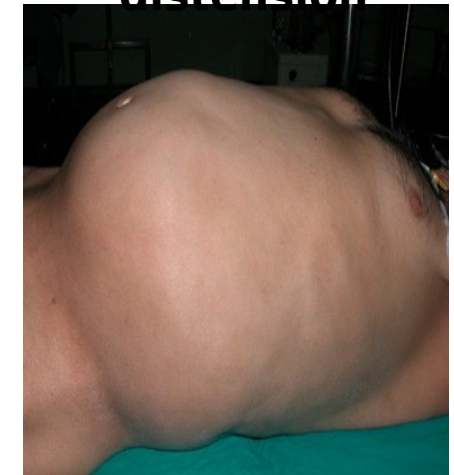
The bacteria in the colon ferment the lactose into a variety of gases, leading to increased flatulence

Explain on biochemical basis symptoms of Lactose intolerance

unabsorbed lactose increases the osmotic gradient of the luminal contents, secondary drag water in lumen and leads to **Diarrhea**



Abdominal distension



Flatulence



Types (Causes) of Lactose intolerance

- Lactase deficiency may be:

1-Congenital or primary;

Due to a **defect in the gene** producing the enzyme protein .

2-Acquired or secondary (adult hypolactasia):

- The most common type
- Due to Damage of intestinal brush border intestinal enzymes due to :
 - **GIT surgery**
 - **Gastroenteritis** due to mucosal damage , and drugs like chemotherapy.
 - **Age-dependent:** loss of lactase activity and reduction in the amount of enzyme produced with the age.

Diagnosis of Lactose intolerance

- *The commonly used tests are : -*
- **Hydrogen Breath Test**
- **Stool Acidity Test**
- **Mucosal biopsy** confirms the diagnosis.



Treatment of lactose intolerance:

- 1. Intake milk-deficient in lactose as Soy milk**
- 2. Intake of yogurt** (Partly digested dairy products by bacteria → decrease lactose content)
- 3. Lactase enzyme** drops or tablets (**Yeast tablets**) prior to eating
- 4. Treat the cause in secondary type**
- 5. Getting enough calcium and vitamin**

Sucrase-Isomaltase deficiency

- These 2 enzymes are synthesized on a single polypeptide chain, hence , their deficiencies coexist.
- **Signs and symptoms**
- Same as that of lactose intolerance (but following Sucrose containing food e.g. sweets and fruit juice)
- History confirms the diagnosis.
- Most confirmatory test is mucosal biopsy.



<https://www.pinterest.co.uk/pin/401242648053224987/>



<https://www.myguthealthtoday.com/eight-facts-sucrose-intolerance/>

Milk intolerance result from the deficiency of the digestive enzyme:

☒ A. Lactase

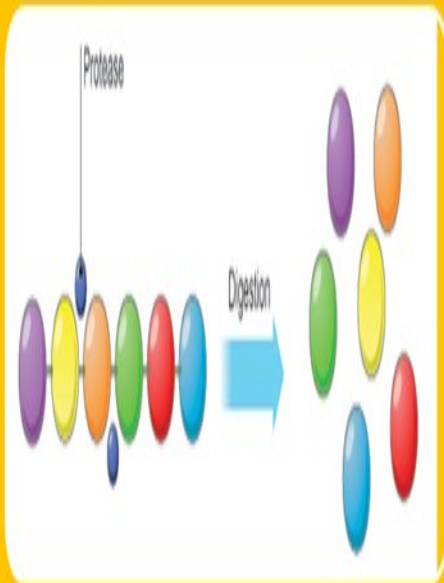
B. Lipase

C. Rennin

D. Trypsin

E. Amylase





Protein digestion

Digestion of proteins



Proteins are first **digested** and hydrolyzed to amino acids

Amino acids (AA's) are then **absorbed**.



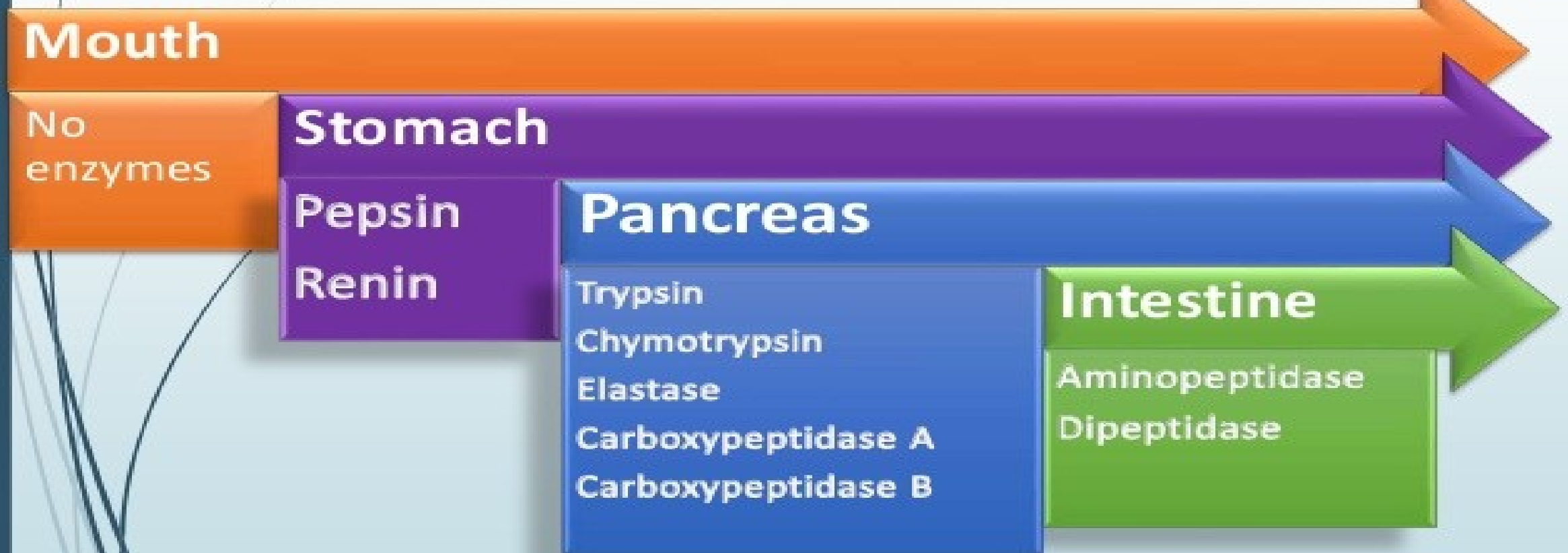
A.A.'s in the blood are called **amino acid pool**



<https://www.slideshare.net/ashokktt/digestion-and-absorption-of-proteins-44933621>



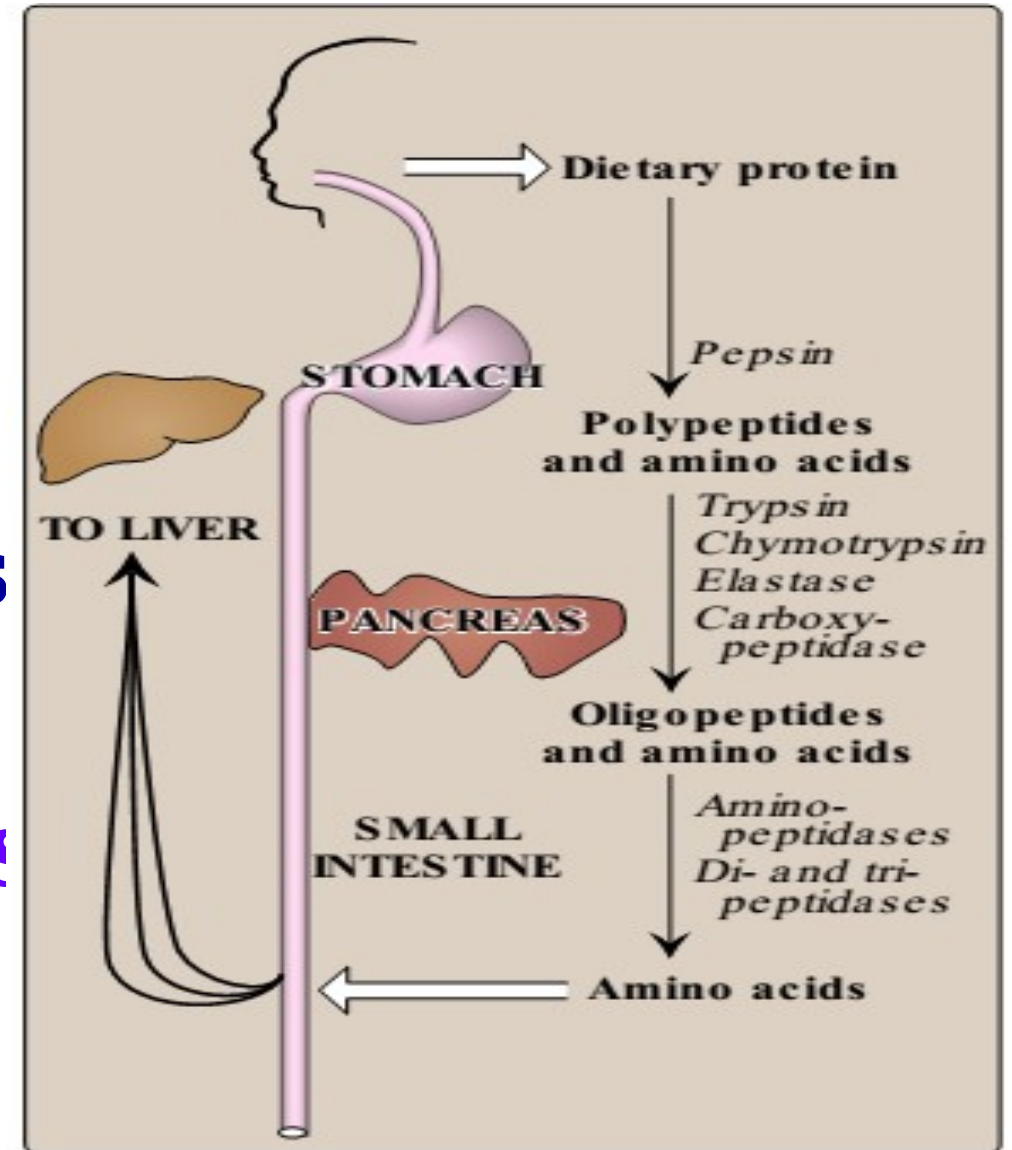
Digestion of Proteins (Overview)



Phases of proteins Digestion



1. Gastric phase
2. Pancreatic phase
3. Intestinal phase



Digestion of dietary proteins by the proteolytic enzymes of the gastrointestinal tract

hydrolyses the peptide bond adjacent to acidic or aromatic amino acids.	endopeptidase	Pepsin	Gastric -1 phase
hydrolyses the peptide bonds containing the carboxylic group of basic amino acids (arginine)	endopeptidase	Trypsin	-2 Pancreatic phase
attacks the peptide bonds formed by carboxylic group of aromatic amino acids, e.g. (phenylalanine)	endopeptidase	Chymotrypsin	
hydrolyzes the peptide bonds next to some non-polar amino acids such as (glycine & alanine)	endopeptidase	Elastase	
It acts on the C-terminal peptide bond.	Exopeptidase	Carboxypeptidase	
separating the N - terminal amino acids in oligopeptides	Exopeptidases	Amino-peptidases	-3 Intestinal phase
act on tri- & dipeptides producing free amino acids		Tri-peptidases & Di-peptidases	



https://www.liverpool.ac.uk/~agmc/en/Medpracs/practical_3/theory_3.html

: Gastrin stimulates release of
HCL from parietal cells

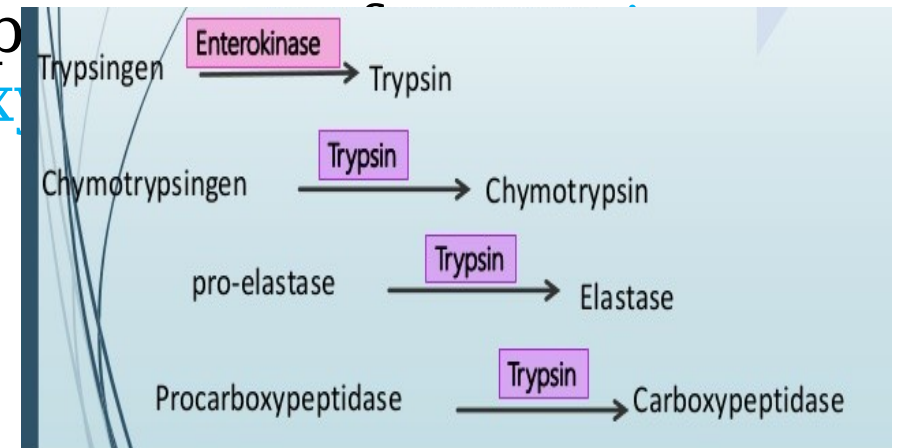
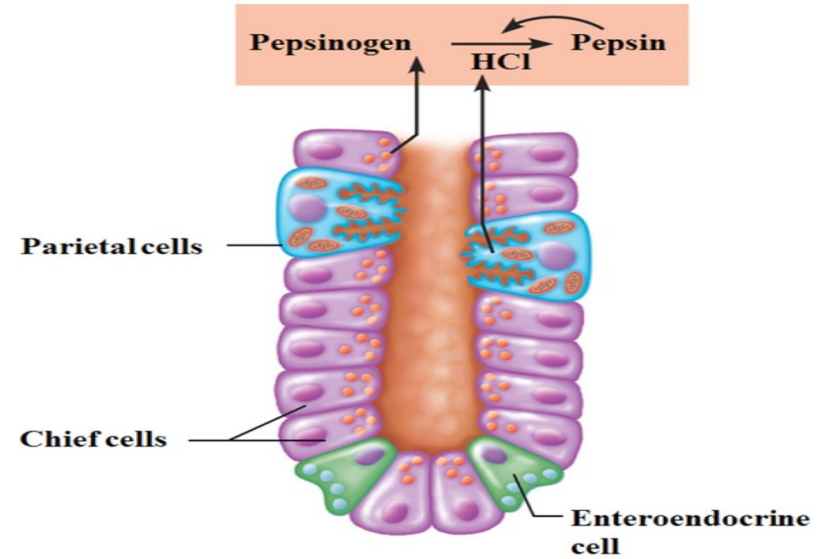
Pepsin from chief cells

proteins $\xrightarrow{\text{Pepsin} + \text{HCL}}$
+ a.a.s

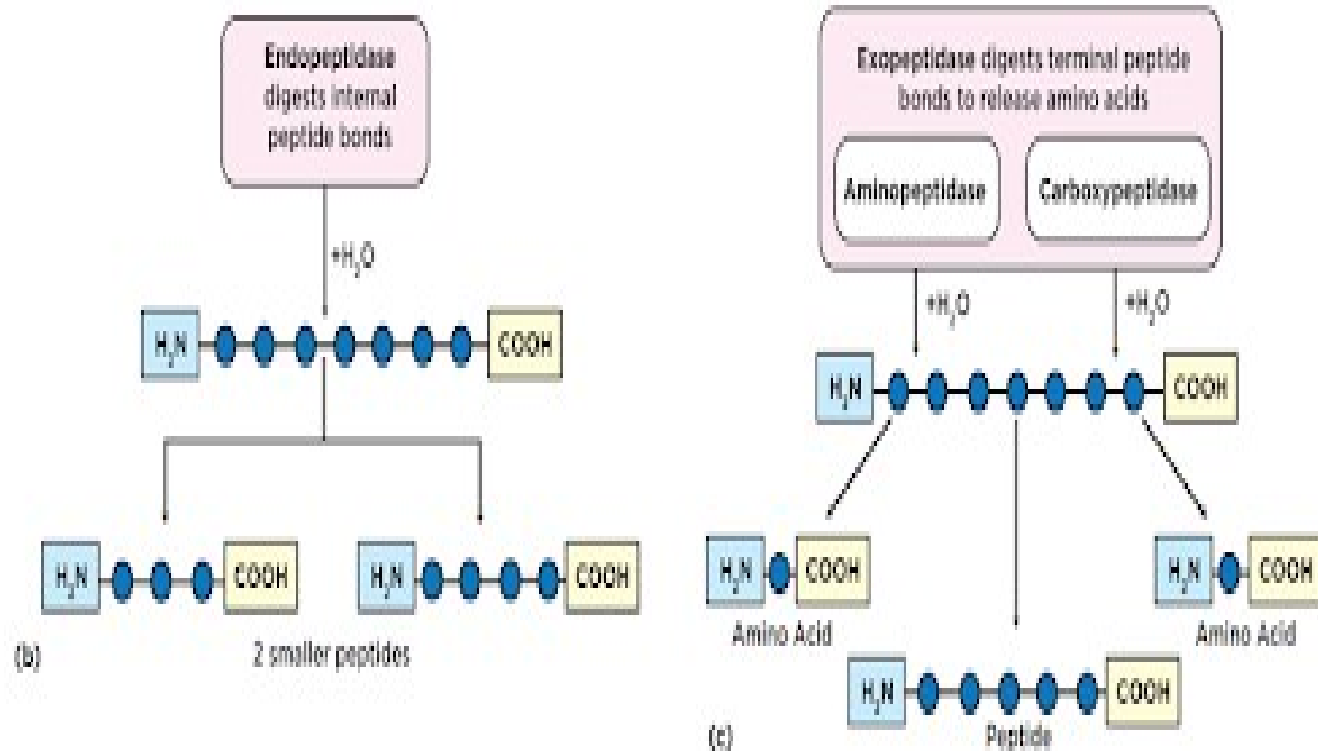
smaller polypeptides

Most of these proteolytic enzymes are secreted
as zymogens (Pepsinogen, trypsinogen, chymotrypsinogen,
proelastase, and procarboxypeptidase are p
trypsin, chymotrypsin, elastase, and carboxy
respectively)

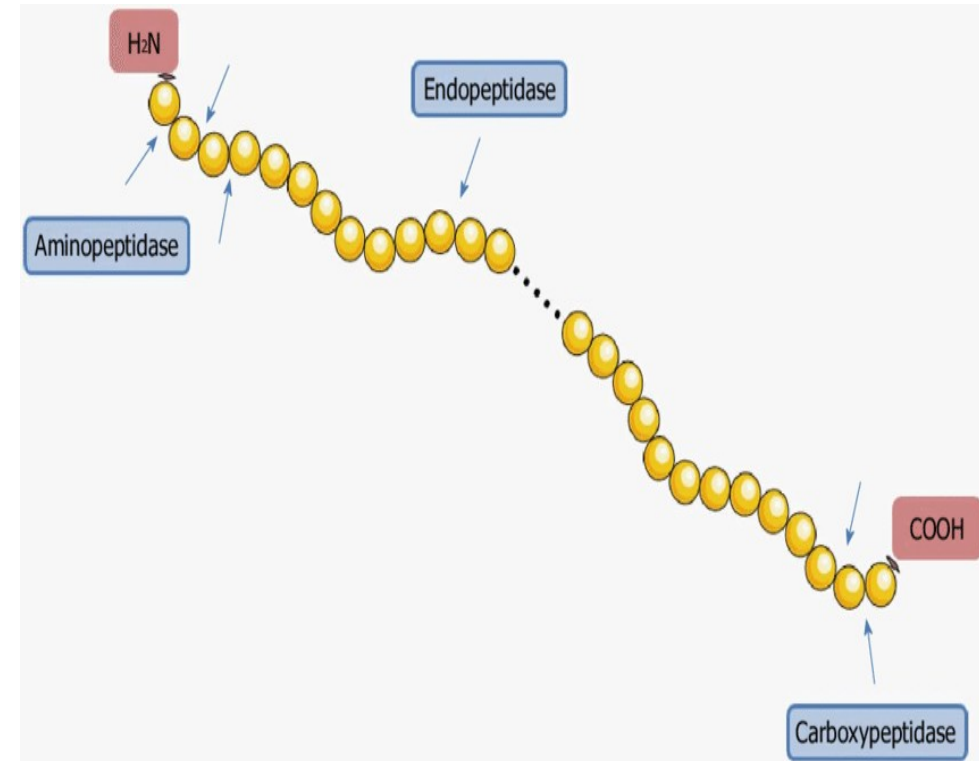
<https://www.slideshare.net/ashokktt/digestion-and-absorption-of-proteins-44933621>



Endopeptidase vs exopeptidase



https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.deerland.com%2Fglutalytic%2Fgluten-digestion%2F&psig=AOvVaw005jv-WHpGON3Vi57_AdTS&ust=1597330797347000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCliz3_71lesCFQAAAAAdAAAAABAD

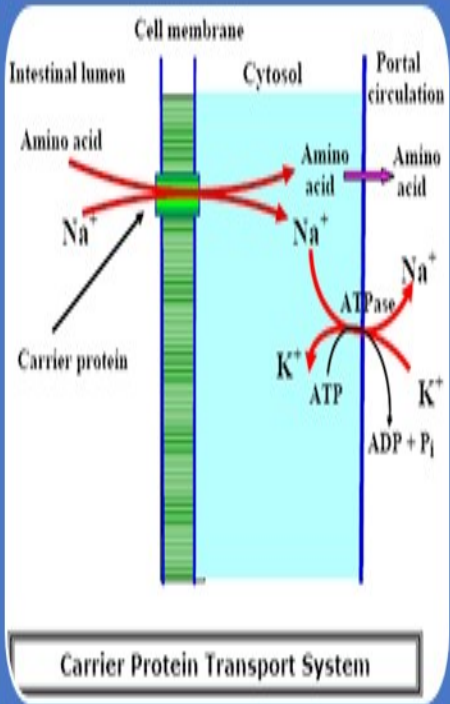


https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FSimplified-representation-of-the-concept-of-endo-and-exopeptidases-Endopeptidases-cleave_fig1_311750351&psig=AOvVaw005jv-WHpGON3Vi57_AdTS&ust=1597330797347000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCliz3_71lesCFQAAAAAdAAAAABAJ

From the pentapeptide,
phe-ala-lys-arg-leu,
Arginine residue is split off by:

- a. Trypsin
- b. Chymotrypsin
- c. Aminopeptidase
- d. Carboxypeptidase



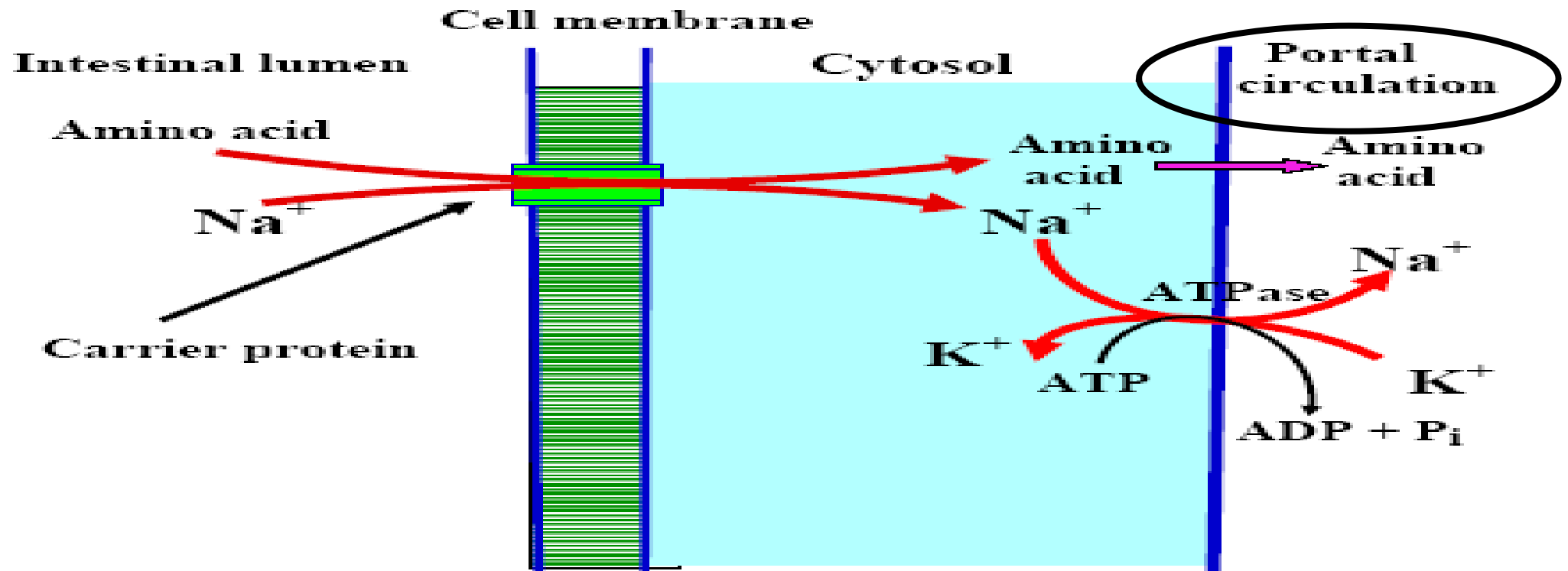


Absorption of amino acids

Absorption of amino acids

Active transport

a protein carrier mediated - system requiring **ATP** obtained from **Na / K - ATPase**.



Key Points



- Dietary carbohydrates can be digested mainly by amylases and disaccharidases with minimal contribution of the stomach.
- Many fibers are not digestible. However, they should be obtained in diet.
- Adult hypolactasia is common amongst most of the world's population.
- Digestion of proteins starts in the stomach with completion by pancreatic and intestinal phases.
- Most of the proteolytic enzymes are secreted as zymogens (inactive precursors).
- Absorption of amino acids occurs by means of active transport.

SUGGESTED TEXTBOOKS



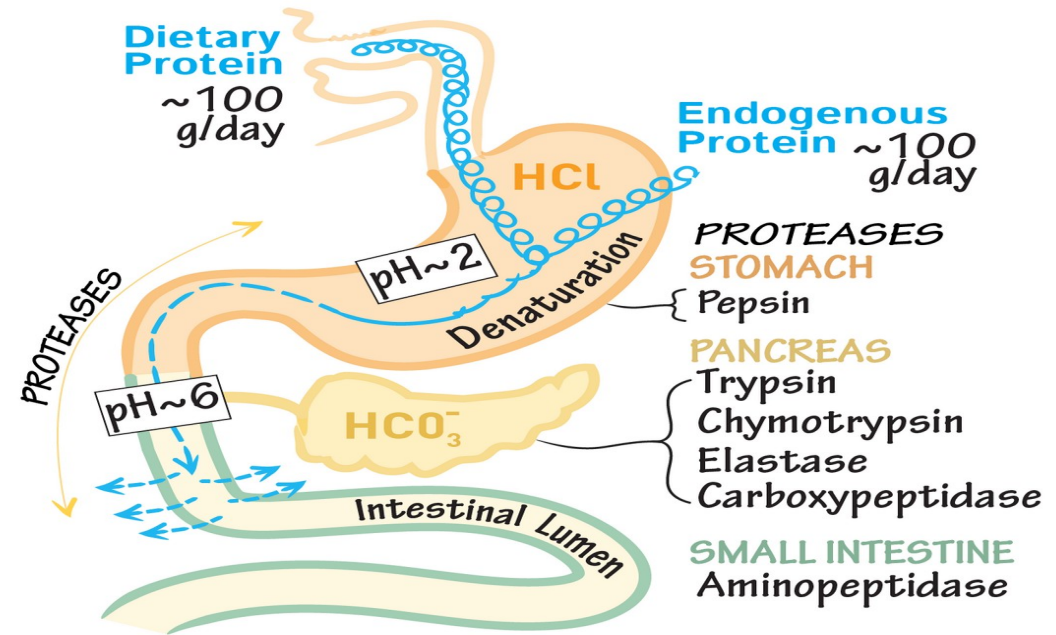
- "Lippincott's Illustrated Reviews in Biochemistry" by P.C.Champe, R.A.Harvey and D.R.Ferrier
- "Harper's Biochemistry" by R.K.Murray, D.K.Granner, P.A. Mayes and V.W.Rodwell.
- Fundamentals of Clinical Chemistry (Tietz) Sixth
- "Textbook of Biochemistry with Clinical Correlations" by T.M.Devlin
- **www.namrata.co- *Biochemistry for medics***

Thank you

Action of proteolytic enzymes

Enzyme	Hydrolysis of bonds formed by carboxyl groups of
Pepsin	Phe, Tyr, Trp, Met
Trypsin	Arg, Lys
Chymotrypsin	Phe, Tyr, Trp, Val, Leu
Elastase	Ala, Gly, Ser
Carboxypeptidase A	C-terminal aromatic amino acid
Carboxypeptidase B	C-terminal basic amino acid

Protein Digestion



Fecal Nitrogen Excretion
Measures protein absorption efficiency.